Active and Passive 3D Vector Radiative Transfer with Preferentially-Aligned Ice Particles

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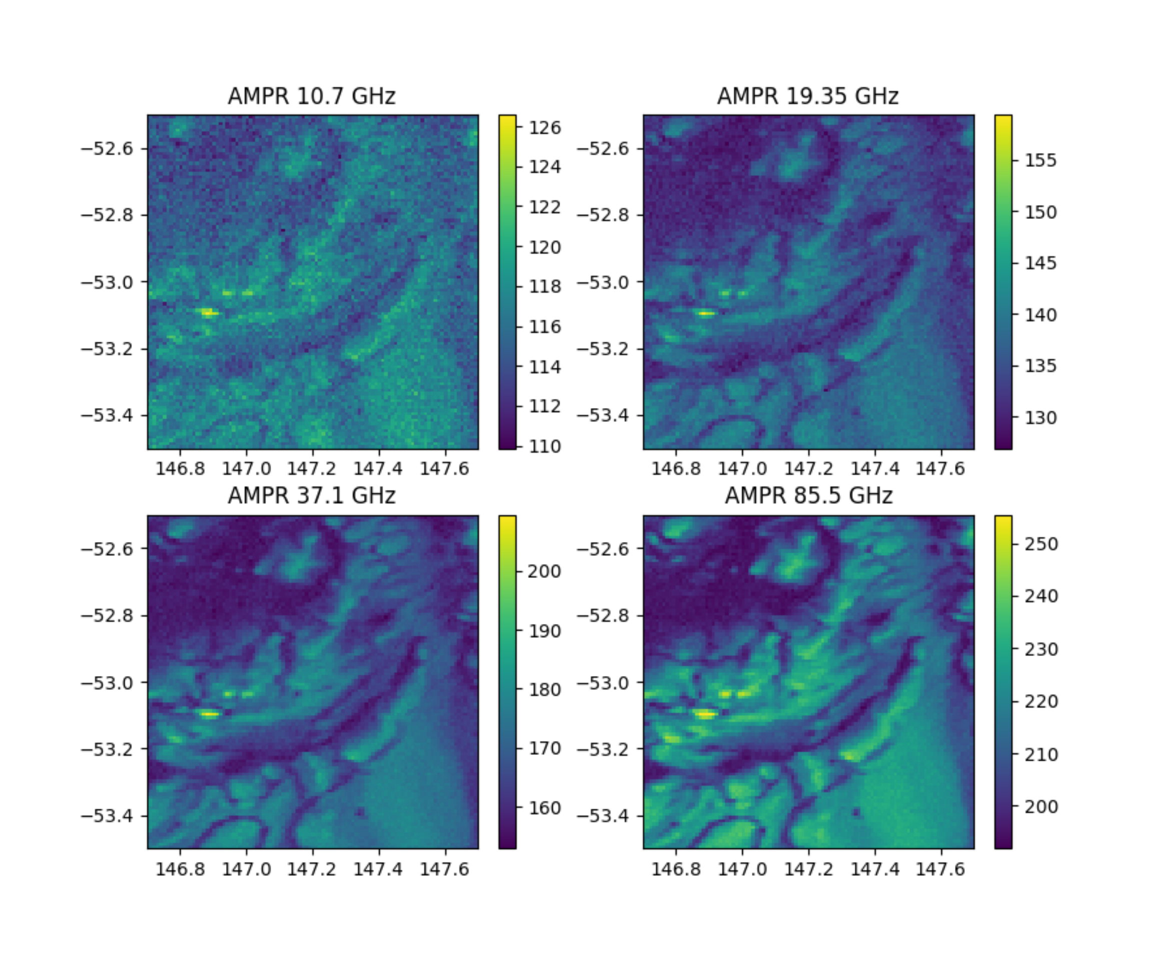
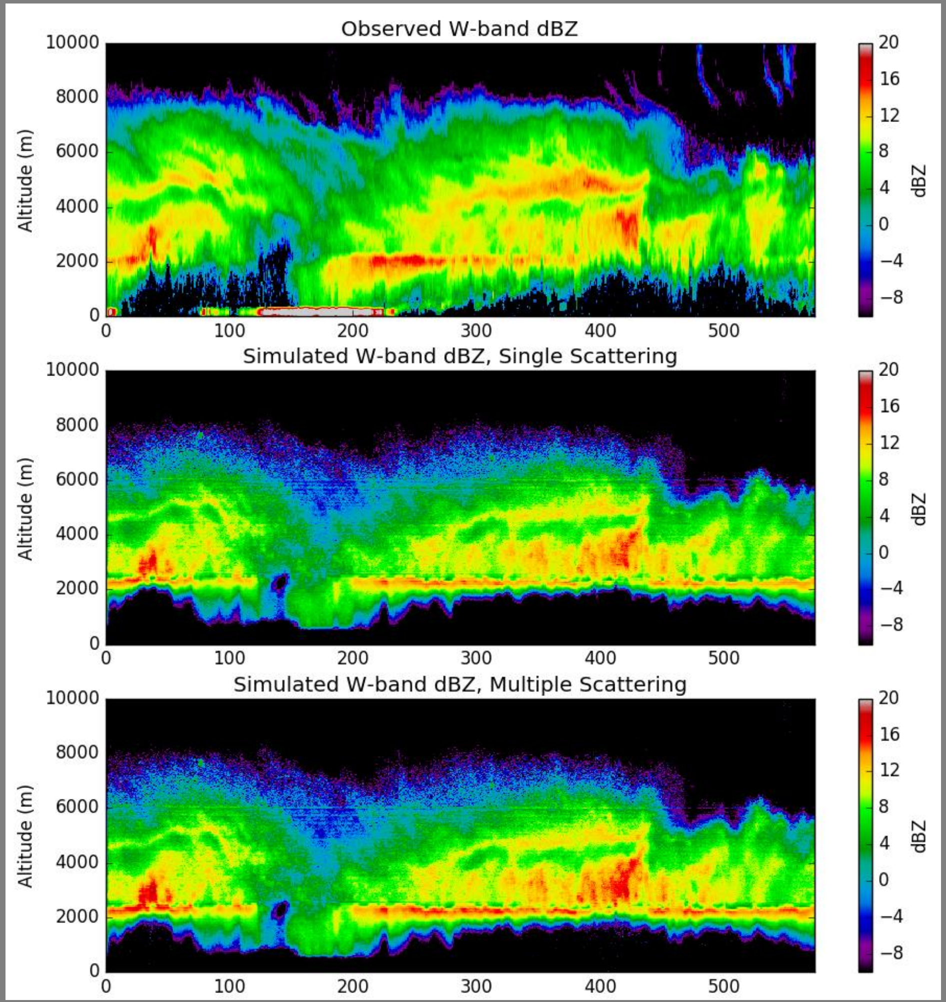
Radiative Transfer Model for Passive Sensors

To solve the radiative transfer equation for microwave and millimeter wave radiometers in three dimensions, we employed the Monte Carlo solver (Davis et al., 2005) in the Atmospheric Radiative Transfer Simulator (ARTS). See Adams and Bettenhausen (2016) for validation of satellite simulations.



Radiative Transfer Model for Active Sensors

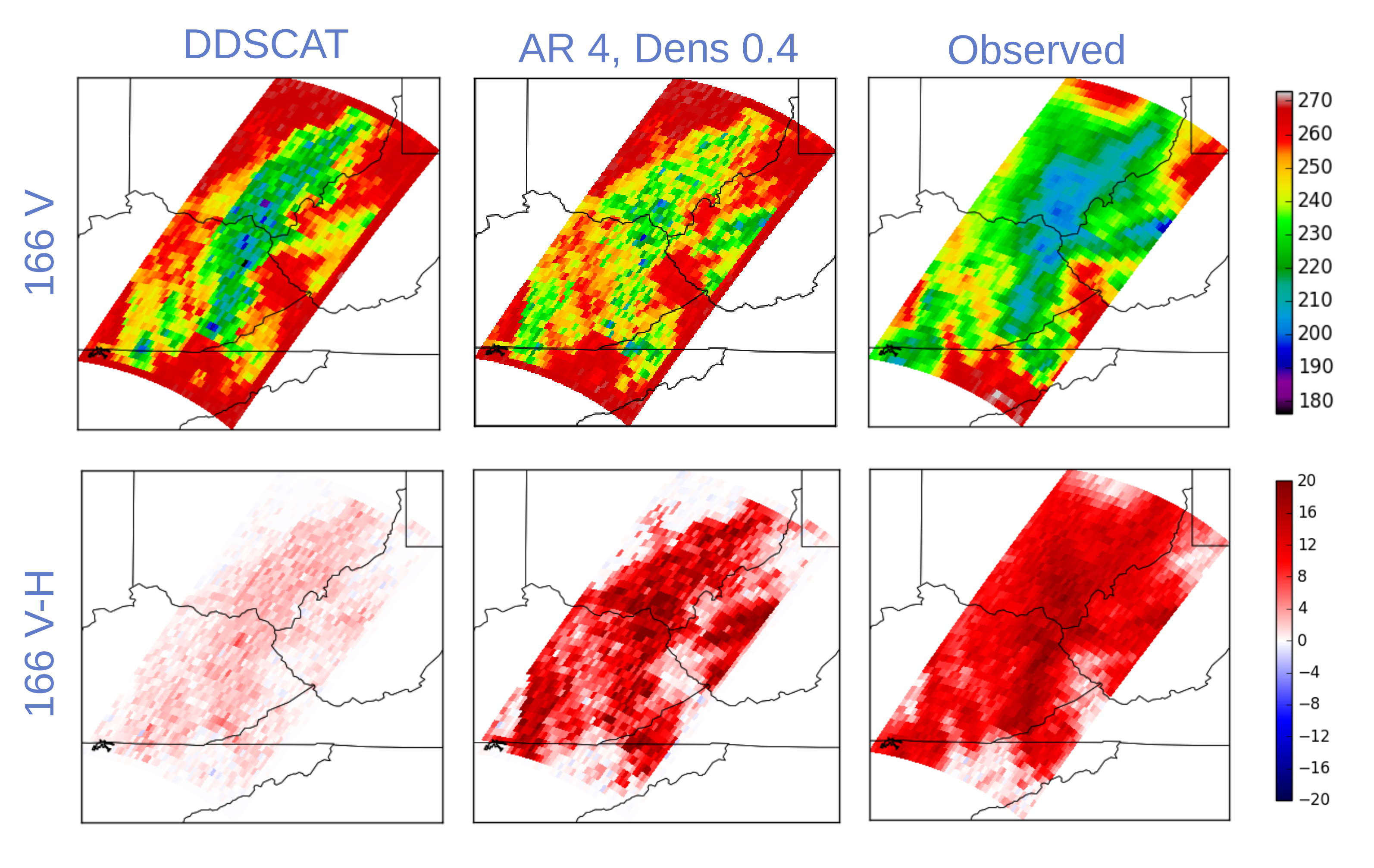
To ensure that we have a radar simulator that uses the same framework as the radiometer simulator and that can handle multiple scattering, we extended ARTS to include Monte Carlo integration for active sensors.



So why do we need more scattering calculations?

Current DDSCAT databases do not include sufficient information to model horizontally-aligned particles

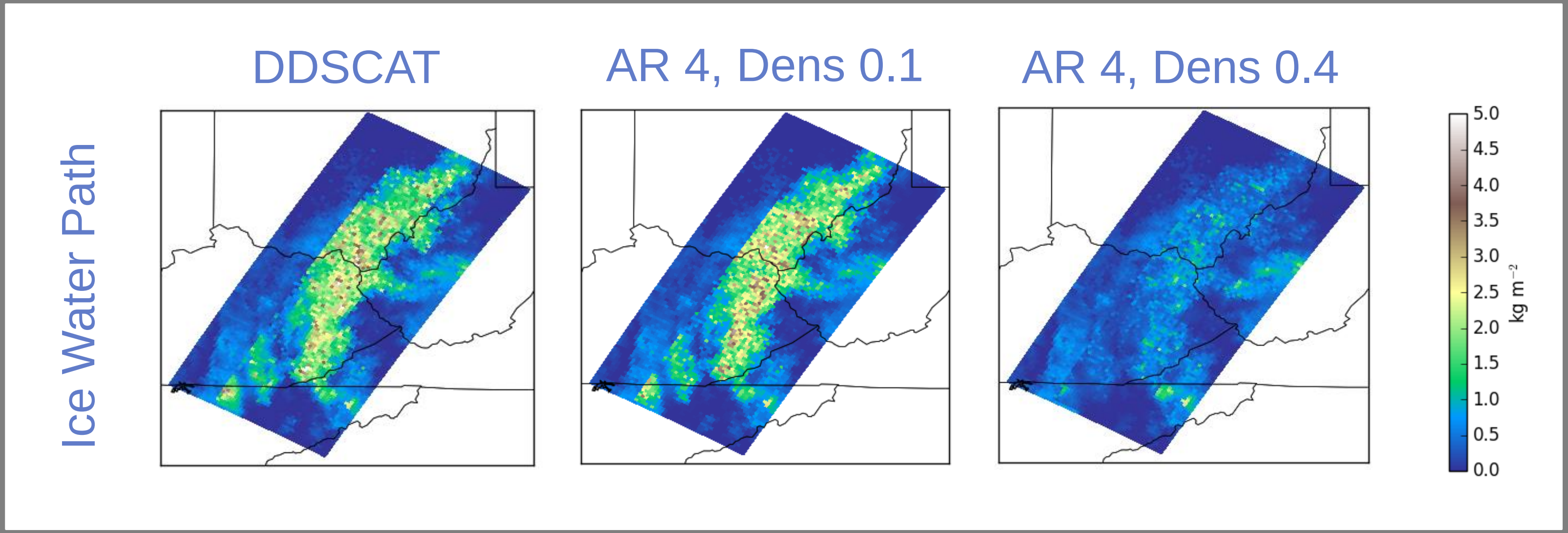
T-Matrix calculations can be used to match intensity and polarization, but…



So why do we need more scattering calculations?

T-Matrix aggregate models cannot both match all sensor observables and expected ice water content

DDSCAT calculations are computationally expensive, so can we supplement existing databases with other calculations?

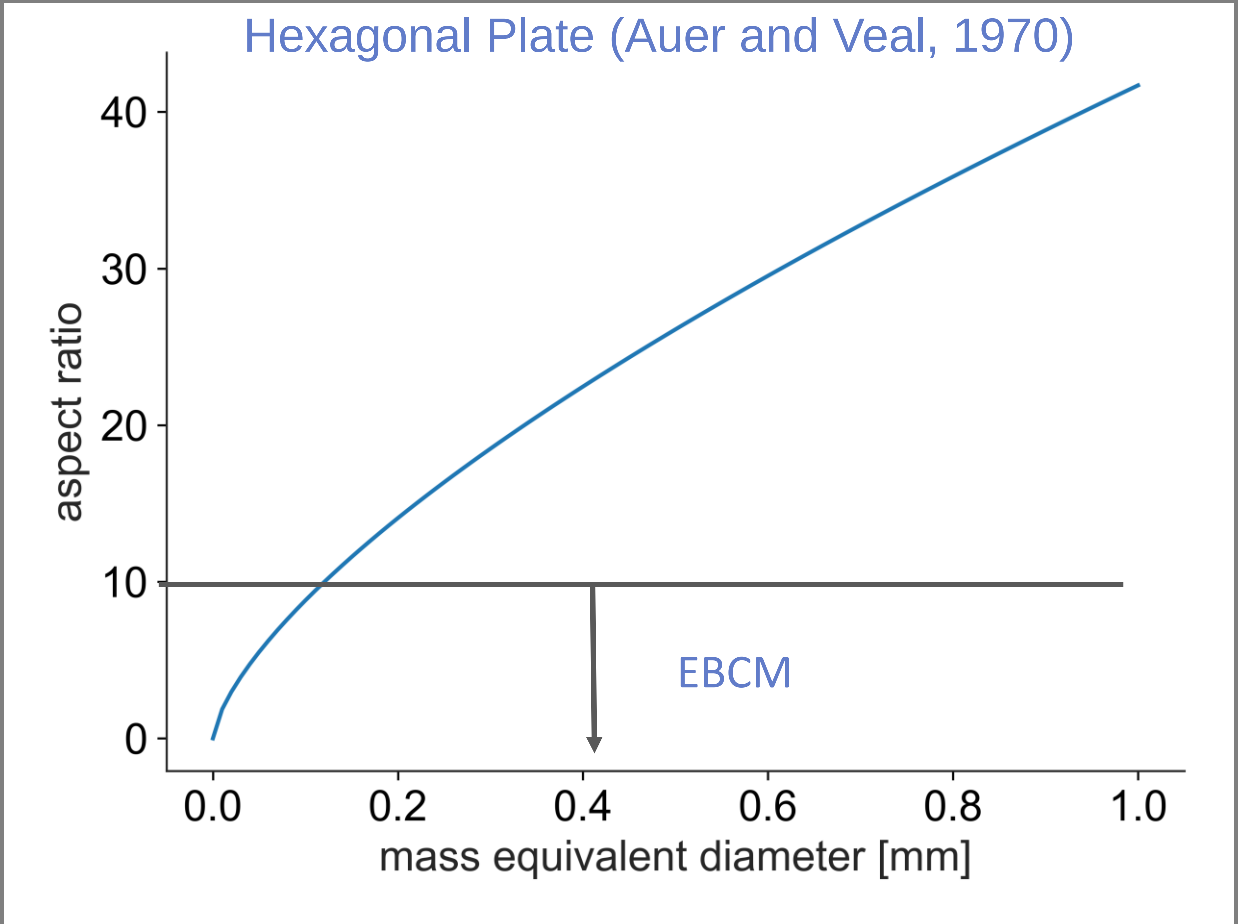


Combining Pristine Geometries with DDSCAT Aggregates

Aggregates tend to have low aspect ratios, and there is debate about the degree of alignment due to complex aerodynamics.

Planar and columnar geometries exhibit more preferential orientations in both models and observations, particularly in the absence of turbulence.

Hexagonal plates can be modeled relatively well with cylindrical plates (Adams and Bettenhausen, 2012).



Invariant Imbedded T-Matrix Method (IITM)

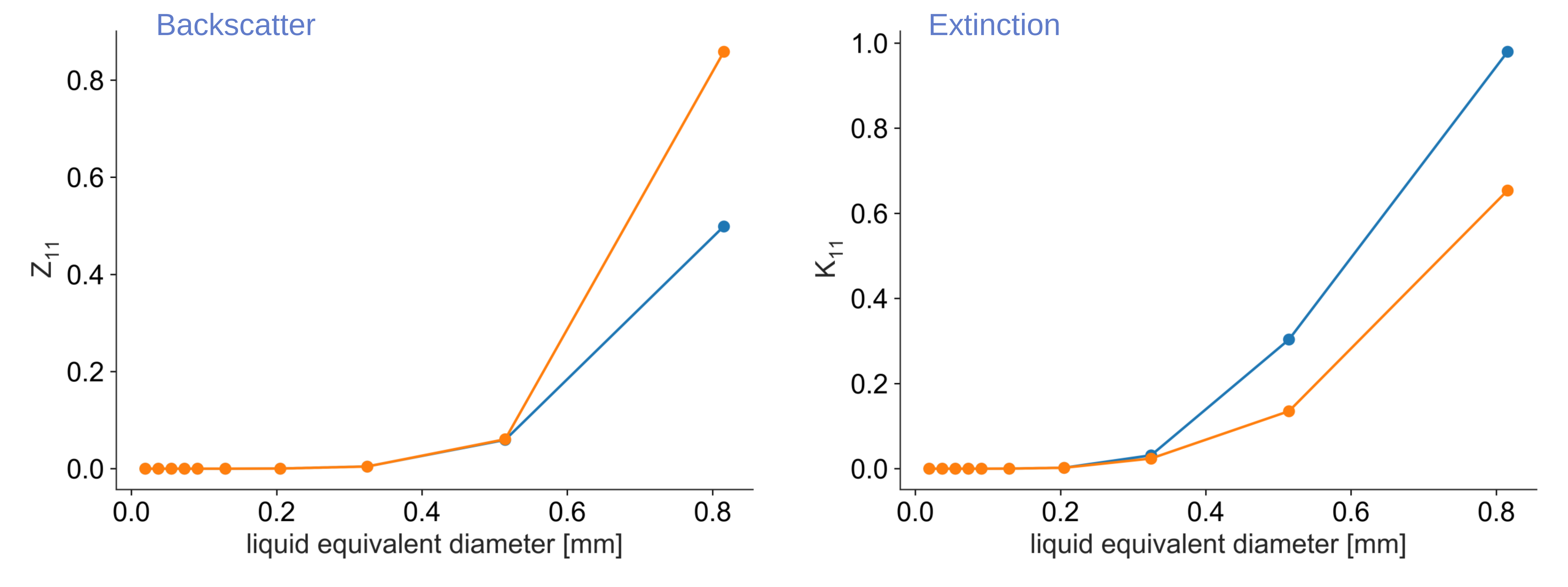
Originally used in quantum mechanics, invariant imbedding has been applied solving electromagnetic scattering problems (Johnson, 1988). IITM can be used to calculate scattering for particles with higher aspect ratios, more complex geometries, and heterogeneous permittivities.

At Goddard, we have developed an implementation of IITM in C++. This codebase will be released via NASA's open source agreement.

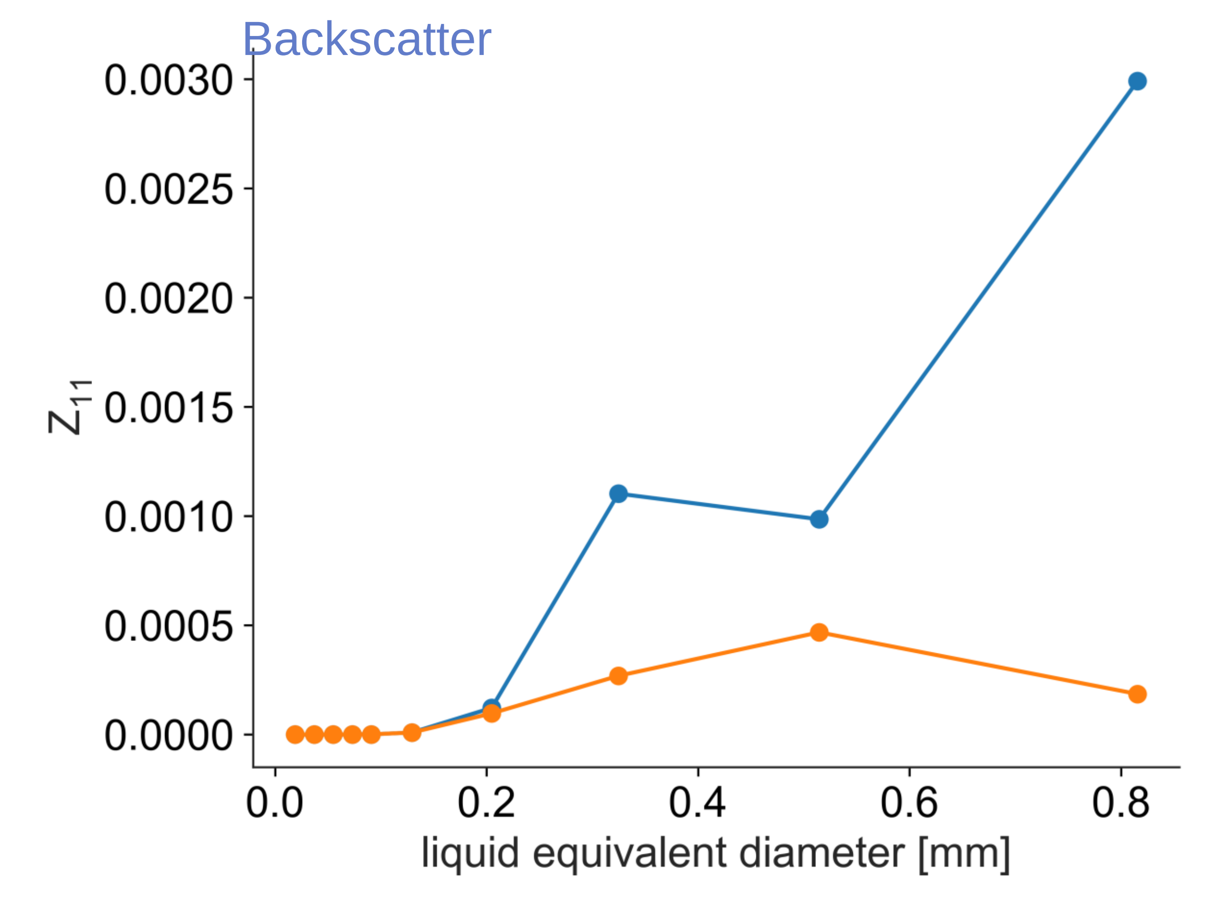
Details

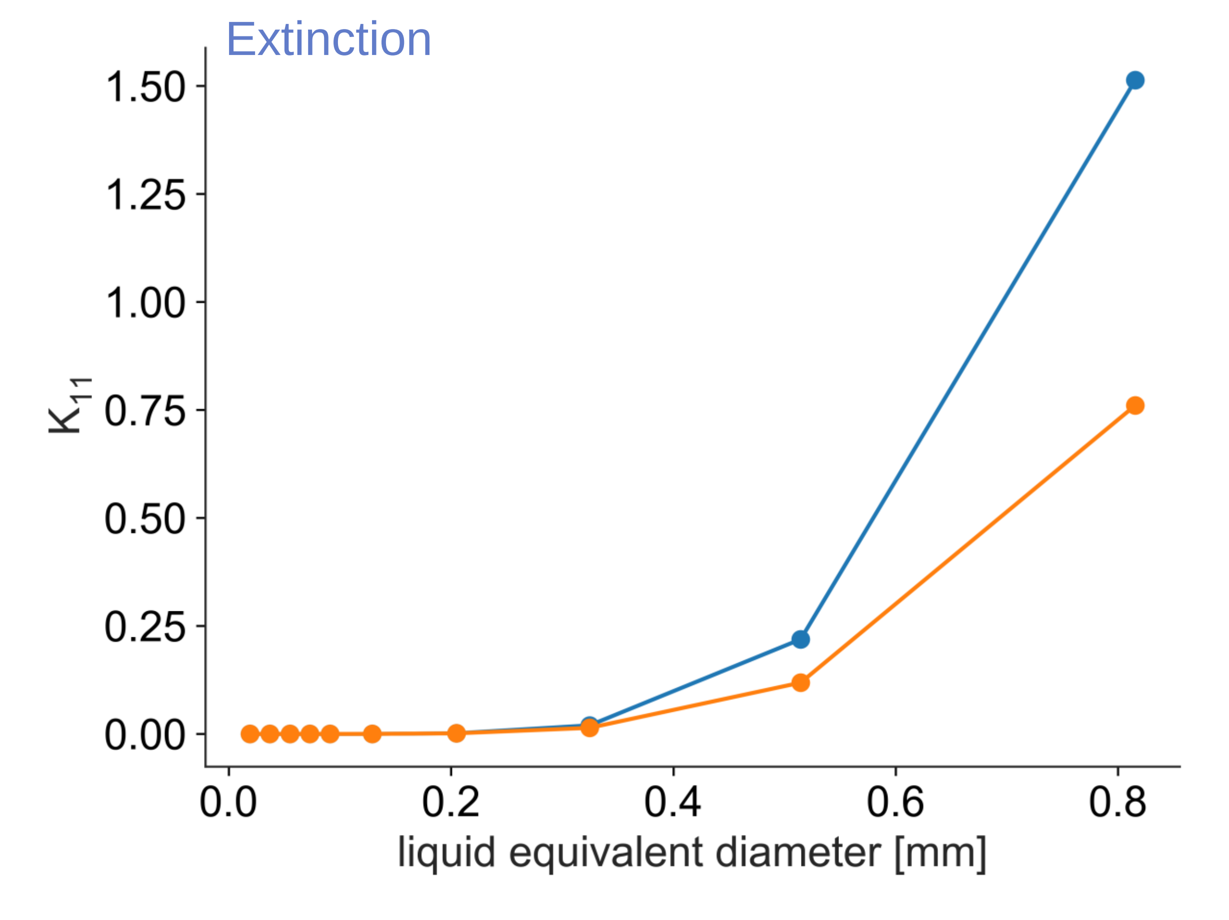
- Mixed precision
  - Quad for special functions
  - Double for linear algebra
- MPI-enabled
- Pre-calculates and stored the T-Matrix
- Julia / C++ interface to load T-Matrix
  - Cross sections
  - Amplitude scattering matrix
  - Orientational averaging

Results for Nadir View (0º zenith angle)

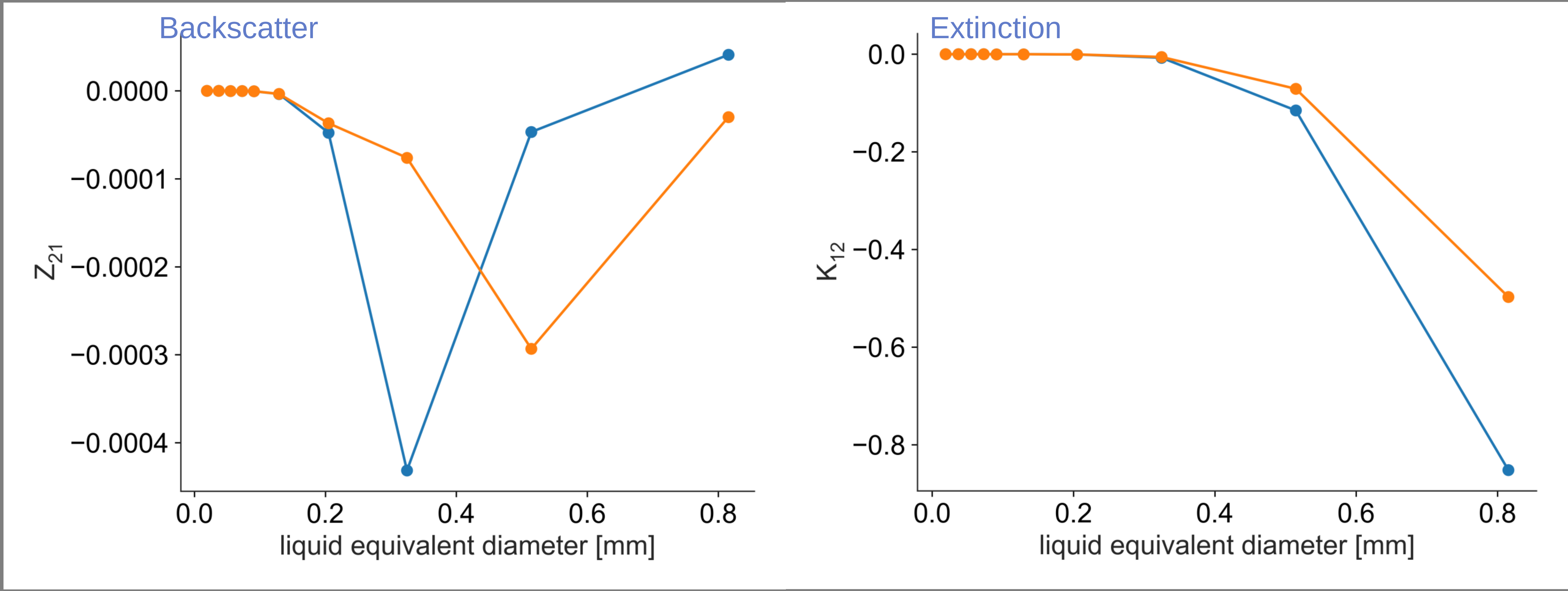


Results for Slant View (50º zenith angle)





Results for Slant View, Cross Terms (50º zenith angle)



Conclusions and Future Work

- Three-dimensional simulations
- Employed IITM to calculate scattering for high aspect ratios
  - Scattering properties deviate from lower aspect ratio EBCM calulations at larger size parameters
- Looking to employ other methods for more complex geometries
  - Boundary Element Method
- Polarized, Fast Radar Solver